IMPACT OF MILITARY WHEELED VEHICLES ON WATER INFILTRATION RATES OF CHIHUAHUAN DESERT SOILS

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DEDICATION

This thesis is dedicated to my parents, Candelaria and Oscar, to my brothers, Alfred and Adrian, and to my little sister, Sandy, for supporting me in every way possible with their love, encouragement, and laughter. Most important for putting up with me when I was not the best company. Thank you guys, I LOVE Y'ALL!!

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by

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THESIS

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ABSTRACT

The study was conducted on McGregor Range, in the Chihuahuan Desert of Southern New Mexico. The objective of the study was to determine the impact of military training maneuvers on soil water infiltration. Treatment consisted of a Humvee making zero, five, and twenty passes at two sites. Five plots were placed within each site and treatments were applied under wet and dry conditions. Infiltrometers were used to determine water infiltration rates.

Data analysis was done using the SAS Proc Mixed Version 6.12 in collaboration with the Biostatistical Laboratory of the University of Texas at El Paso. The analysis was done using two factors, season and treatment. The two season levels were wet and dry conditions. The treatment levels were zero, five, and twenty Humvee passes. A reduced model was used to look at treatment effects, because no significant difference was found between five and twenty passes (active treatment).

Findings indicate that there was an impact on water infiltration rates for Site 1. Site 1 indicates that there was a significant change in the water infiltration rates between the control and the active treatment. The greatest impact for water infiltration rates was under wet active treatments. Rates for active treatments increased close to control levels from 1996 to 1997. Site 2 did not demonstrate any significant difference between infiltration rates for any of the factors. The difference between the response of both sites could be due to differences in vegetation, soil composition, and soil structure.

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INTRODUCTION

The Chihuahuan Desert is a high-elevation desert with rough mountainous terrain. These characteristics, similar to those of many political "trouble spots" of the world, make it an ideal site for military training. McGregor Range, located on the Fort Bliss Army reservation in southern New Mexico (Fig. 1), is part of this area and is extensively used for training exercises. Although, the area has an appearance of ruggedness and resistance to environmental stress, it can easily be destroyed. The area is characterized by an arid climate, with an average precipitation of 20 cm a year, with more than half of it occurring from July to September (U.S. Army Corps of Engineers Fort Worth District, 1994). This low rainfall makes recovery a very slow process (Mackay & Herrick, 1997).

McGregor Range covers a large region of south-central New Mexico. The range can be divided into three main physiographic areas, each with their own distinct vegetation and soils. The Hueco Basin forms the western part of the range. The basin is a shrubby desert dominated by creosote bush and mesquite enclosing smaller patches of grass (Johnson, 1997). The major soil associations include the Mimbres-Tome and the Pintura-Dona Ana (Fig. 2) (Derr, 1981). Overall, the soils reflect wind modification of the desert floor. The Hueco Mountains form a north-south ridge through the range, approximately along the western boundary of the Grazing Units Area (Fig. 1) (U.S. Army Corps of Engineers Fort Worth District, 1994). The soils are generally very thin, over rock outcrops and belong to the Lozier Rock outcrop association (Fig. 2) (Derr, 1981). Otero

Mesa, which is the area where I am doing my study, is a flat eastward tilted plateau that slopes gently away from the crest of the Hueco Mountains. Soils in this area are mostly part of the Philder association and are thick sandy and silty soils accumulated on limestone and sandstone bedrock (Johnson, 1997). Most of the soils present in this area range from excessively drained sands to indurated caliche or bedrock near the surface (Derr, 1981). The soil type present in the study sites generally consisted of Philder very fine sandy loam (PEC) soils (Fig.2), which are generally made up of a shallow soil layer over caliche (U.S. Army Corps of Engineers Fort Worth District, 1994). The permeability of this soil is moderate, and though the available water capacity is very low, the caliche layer keeps the water within the top 50 cm and thus makes it available to many plants (Derr, 1981).

The vegetation of this area consists mostly of shrubs and grasses of which creosote bush is dominant in most areas (U.S. Army Corps of Engineers Fort Worth District, 1994). In some areas, grasses are lacking and these zones are subject to severe erosion. Further disturbance may reduce the infiltration of water, increase erodibility and reduce the density of grasses even further (U.S. Army Corps of Engineers Fort Worth District, 1994). All of these characteristics make management of timing, intensity and frequency of use important factors in order to ensure future use and to limit environmental impact of military vehicles used in training exercises (Thurow et al., 1995).

An understanding of the impact of wheeled vehicle maneuverings on the soil is needed in order to effectively manage the area. The capacity of the environment to recover will ultimately be determined by the interaction between the environment and

vehicle traffic. This study will focus on the impact of military exercises (vehicle traffic) on water infiltration rates into the soil. This is only one of the aspects being examined as part of a larger study (Mackay & Herrick, 1997).

Water infiltration rates are determined by many factors. One of these factors is the soil composition, since the presence of clays in the soil reduces the rate at which the water infiltrates (Hillel, 1971). In a coarse-textured soil (possibly sandy) above a finer-textured soil (such as clay) the infiltration rate is initially rapid, but then decreases to that of a fine-textured soil (Balba, 1995). The rockiness and vegetation of the area also affect the water infiltration rate. A soil layer in a forest will have greater infiltration rates than a compacted soil surface with little or no vegetation (Ward & Elliot, 1995). A crust on the surface can also impede water infiltration because the crust has greater density, finer pores, and lower conductivity. The effectiveness of the soil crust on decreasing water infiltration is only initial since as the wetness of the soil depth increases the effect of the crust decreases (Hillel, 1971). Other factors are the size and number of macropores present in the soil. These may collapse when vehicles drive across the soil (Thurow et al., 1995). The macropores influence water flow in the soils as the water reaches saturation or as vertical flow exceeds the infiltration capacity of micropores (Iwata et al., 1988). Soil compaction has an effect on water infiltration because it restricts the movement of water into the soil profile (Ward & Elliot, 1995). The subsurface hydrology of a soil is also greatly affected by compaction, because the denser soil reduces infiltration and hydraulic conductivity (Gatto, 1998). Moisture content is a factor that affects soil

strength, which is what makes the season of treatment such an important factor in water infiltration. Finally, one of the major factors affecting the water infiltration rate was the number of passes that were applied to each of the transects in this study (Thurow et al., 1993).

HYPOTHESES

Treatments made when the soil was wet and increasing number of passes by the Humvee on each transect will result in greater soil compaction and a decrease in the water infiltration rate.

Treatments made when the soil was dry and reduced number of passes by the Humvee on each transect will result in less soil compaction and less or no impact on water infiltration of the soil.

The null hypothesis is that season and treatments will have no impact on the rate of water infiltration.

METHODS AND MATERIALS

The experimentation was done at two, 1 km^2, sites chosen within the Otero Mesa of McGregor Range, Otero Co., New Mexico to represent the most common soils in the area (Fig. 3). The locations of the sites in the UTM coordinate system are as follows:

Site 1		Site 2	
NW	431666	NW	431130
	3588873		3585040
NE	432757	NE	432130
	3588705		3585040
SW	431560	SW	431130
	3587964		3584040
SE	432530	SE	432130
	3587716		3584040

Five plots, 100 by 200 meters, were randomly located within each site to be used as independent replicates for each of the treatments (Fig. 4). Within each plot there were six transects that ran south to north and one of the following treatments was applied to each: control (zero Humvee passes), 5 Humvee passes, and 20 Humvee passes for both the dry and wet season (Fig. 5). Treatments of the transects were randomly applied. No rainfall occurred before the dry season treatment (for at least a week) and rainfall occurred within the past 24 hours for the wet season treatments. The dry season treatments for Site 1 were done in May 1996 and for Site 2 they were done in October 1996; the wet season treatments were done in July 1996 for both Site 1 and 2. Infiltration rates and all other testing (bulk density, vegetation, penetrometer, etc.) of these sites were done immediately

after the treatments. Therefore, the first set of data was obtained in 1996 in the summer and fall, and the second set of data was obtained in May of 1997.

Water Infiltration

The purpose of this testing was to determine the capacity of the system to capture water, which was done by timing the infiltration of water into the soil with the infiltrometer. An infiltrometer is an apparatus for measuring infiltration into the soil in which water is applied by sprinkling or flooding. The infiltrometer used in this study consisted of a PVC pipe 20 cm in diameter and 12 cm in height (Fig. 6). The infiltrometer was set on the right track (when facing north) or about one meter from the edge of the transect for the control treatment (Fig. 5). Live vegetation cover was recorded as a percentage number. Three randomly selected points along the 100 m transect were determined and the infiltrometer was pushed into the soil and the infiltration rate obtained for each of the rings by recording the amount of time it took for the soil to absorb 393 ml of water (1.25 cm height in the infiltrometer). The infiltration rate for each of the rings was determined as follows: 1.25 cm / infiltration time (in min.). In total, sixteen, 393 ml measurements (~6400 ml) of water were added to the soil. The first four measurements were to wet the top soil, the next four were used to determine the infiltration time and the last eight saturated the soil down to 15 cm. A more detailed procedure of the method used to determine infiltration time and the form used for collecting data (Fig. 18) can be found in appendix A.

Gravimetric Moisture

A period of 18 hours was then allowed to pass in order to allow the soil to reach approximately field capacity. After the 18 hours passed, three core samples were taken from within the infiltration ring. The corer consisted of three parts: a 5 cm, 10 cm, and 2.5 cm set of rings, 5.2 cm in diameter (Fig. 7). Therefore, the core samples consisted of a volume for the 0 - 5 cm depth (the 5 cm sample) and another for the 5 - 15 cm depth (the 10 cm sample). The 2.5 cm part was used only to drive the corer down to the level of the soil surface. One part of the core sample was placed into a 6 oz. (the 0 - 5 cm depth) and the other into a 8 oz. (the 5 - 15 cm depth) tin with a tight fitting lid. These two tins were then placed in individual ziplock bags and into an ice chest and eventually in the refrigerator when they arrived at the lab. This was done to reduce moisture loss. The soil samples in these two tins were used to determine gravimetric moisture. The other two core samples were placed into two ziplock bags, a small (~17 x 15 cm) ziplock bag was used for the two 0 - 5 cm samples and a large (~27 x 28 cm) ziplock bag for the two 5 - 15 cm samples. These two bags were then allowed to air dry and were used to measure bulk density and carbon and nitrogen content of the soil.

The gravimetric moisture was obtained by weighing the soil in the two tins, drying them at 60 ° C for 72 hours, and weighing them again. The masses were adjusted for the mass of the tins.